

Planning Report No. 35-9

*Proposal for a 60-Inch
Telescope*

Space Sciences Division

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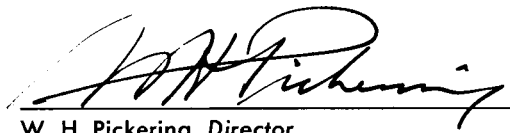
**JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA**

December 31, 1963

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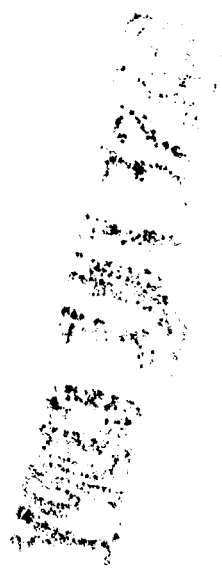
Space Sciences Division

A handwritten signature in dark ink, appearing to read 'W. H. Pickering', written over a horizontal line.

W. H. Pickering, Director
Jet Propulsion Laboratory

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

December 31, 1963



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I. INTRODUCTION

In 1959 the Jet Propulsion Laboratory (JPL) was given responsibility by the National Aeronautics and Space Administration (NASA) for conducting unmanned exploration of the Moon, the planets, and interplanetary space. The *Ranger*, *Mariner*, and *Surveyor* programs are the immediate implementation of this responsibility. The first formal JPL document on the space program (Ref. 1) recognized, however, that spacecraft alone could not give a program producing the maximum overall progress most quickly and with minimum cost. Although many types of information can be obtained with equal accuracy from either ground-based observations or spacecraft, ground-based measurements can be accomplished at substantially smaller cost. Furthermore, the useful lifetimes of present spacecraft are quite limited, and the timing of the spacecraft controlled by the inexorable laws of celestial mechanics. Thus programs requiring similar observations over a long period of time must be made from Earth. A balanced national program of planetary and interplanetary science must, therefore, include extensive high-quality ground-based observations. It is now well known that existing observatories in the U.S. are unable to provide the observing time on suitable instruments required to provide balance in the space program. The Jet Propulsion Laboratory proposes to take steps to remedy this unsatisfactory situation by constructing a 60-inch telescope, oriented towards planetary studies, for use by space scientists.

The first step in this direction was taken by JPL in 1961 through the establishment within its Space Sciences Division of a small group of astronomers whose principal interests were in planetary astronomy. This group has made significant progress, utilizing data already existing in observatory plate collections, and taking new data

when possible with major instruments. The second step was taken in the fall of 1961 with the acquisition of a modest 16-inch telescope, which was placed at the excellent observing site at Table Mountain, California, previously established by the Smithsonian Astrophysical Observatory and used by that group for some 35 years, and now operated by JPL. Figures 1 and 2 show the site and the 16-inch telescope. The Table Mountain site is about 65 miles from JPL, at an altitude of 7500 feet, and is easily accessible year-round by paved highways. It enjoys excellent seeing, and is untroubled by the smog and scattered city lights which plague observatories closer to Los Angeles.

Present observatory facilities were completed in October 1962, and the observatory carried out a major program during the period surrounding the inferior conjunction of Venus in November 1962. Since that time, lunar and planetary photography has been regularly carried out. A half-meter spectrometer and a twin-tube photoelectric photometer have been added recently to the observatory, and at various times high-speed motion picture and closed-circuit television equipment have been used. Figures 3 and 4 show examples of celestial photography with the 16-inch telescope.

The Jet Propulsion Laboratory now proposes to construct a general purpose reflecting telescope of 60-inch aperture, with the telescope and accompanying facility being designed to be especially suitable for high-quality spectroscopy in the visible and infrared, an area of critical importance in contemporary planetary astronomy. A more detailed historical background, the outline of a scientific program, equipment needs, a cost estimate, and a personnel survey are given below.

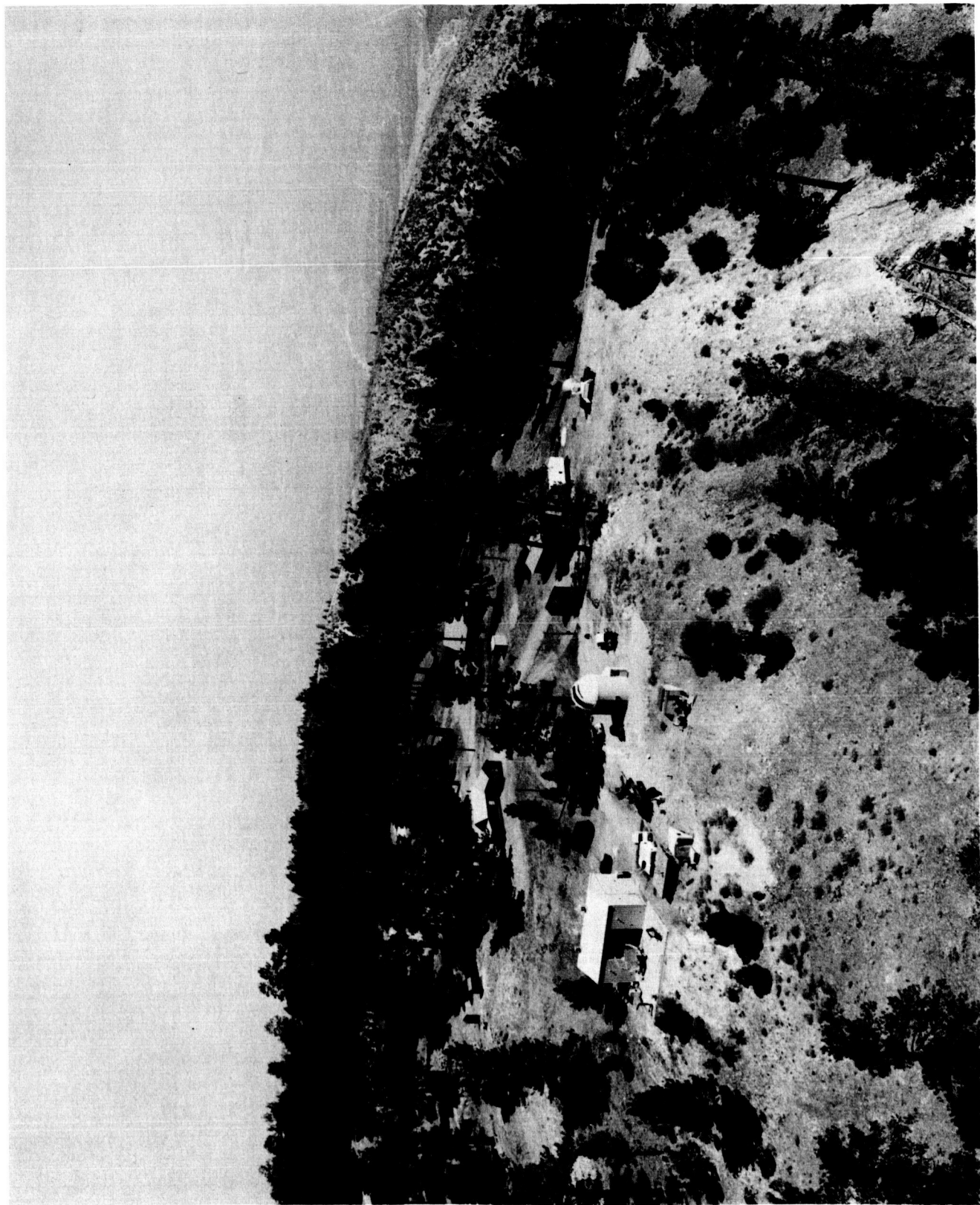


Fig. 1. Table Mountain Observatory. Dome of 16-inch telescope, and 10-foot millimeter wave telescope are visible. The large metal building is presently used in connection with the testing of solar power panels for spacecraft

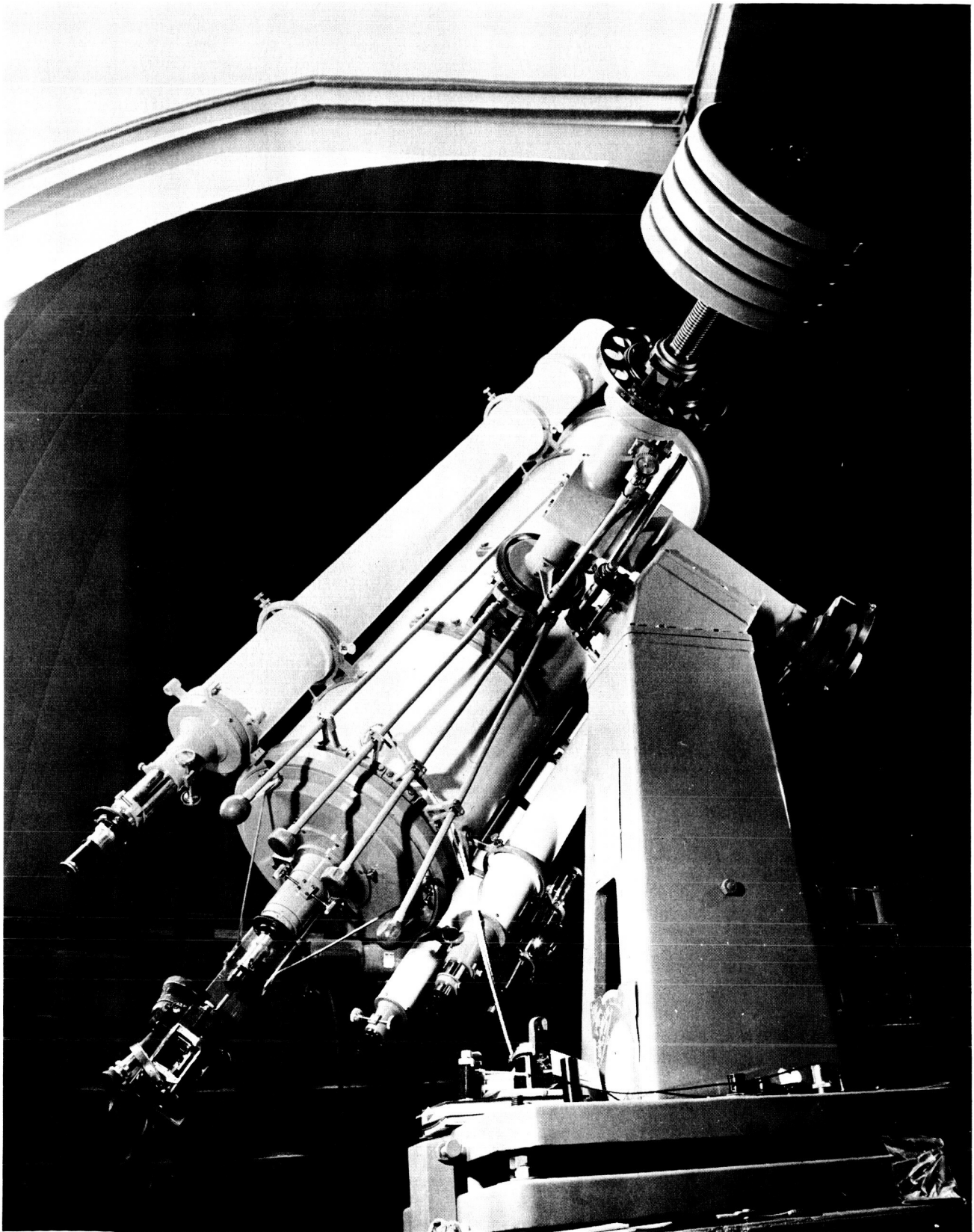


Fig. 2. The 16-inch telescope. A reflector of $f/20$ focal ratio at the Cassegrain focus



**Fig. 3. The Moon. Region of the straight wall.
Photographed by the 16-inch telescope**



**Fig. 4. The Moon. Region of Aristarchus. Photographed
with the 16-inch telescope on Panatomic film
with a 0.2-second exposure**

II. PLANETARY ASTRONOMY

During the 17th, 18th, and 19th centuries, planetary astronomy, including its theoretical branch, celestial mechanics, made up 95 percent of astronomy. The problem of explaining quantitatively the motions of the Moon and planets forced the development of Newtonian mechanics, while the development of mechanics demanded better planetary observations.

During the 19th century physicists began to achieve a qualitative understanding of the interactions of radiation and matter. Astronomers were at last given a tool which seemed to offer hope of some understanding of the enigmatic universe beyond the solar system. By 1907 George Ellery Hale (Ref. 2) was able to state that "in astronomy the introduction of physical methods has revolutionized the observatory, transforming it from a simple observing station into a laboratory, where the most diverse means are employed in the solution of cosmical problems." Hale proceeded to launch the new science of astrophysics in an all-out assault on the fundamental problems of stellar evolution.

During the ensuing half-century astrophysicists plunged into stellar and galactic problems, seldom to return to the more mundane affairs of the solar system. Only the Sun received significant attention, for it is a star. In fact, planetary astronomy gradually acquired a bad reputation

as a result of overly enthusiastic Sunday supplement writers and overly ardent amateur astronomers with little training in physics. Hale never intended for this to happen. He wrote that the problems of astronomical evolution could be considered solved only when we understood the formation of a planet like the Earth, that the astrophysicist's work ended only when he began encroaching on the domain of the geologist.

During the 1930's a few professional astronomers made short excursions into planetary astrophysics which resulted in significant contributions. From World War II to the advent of the space program, however, the number of active planetary astronomers in the United States could be counted on the fingers of one hand, and of those, only one or two spent a majority of their time in the field. As a result, the eve of the space program found astronomers ill-prepared to describe the solar system thoroughly in quantitative terms. The modern tools of astronomy, the large reflector with high-dispersion Coudé spectrographs, sensitive infrared detectors for spectroscopy and radiometry, modern image orthicons and converters, etc., had been and still are rarely applied to problems of the solar system.

It is proposed to employ the modern techniques of stellar astronomy to attack the numerous outstanding problems in lunar and planetary astrophysics.

III. THE TELESCOPE

Modern technology has produced many significant advances in telescope design. The modern trend is toward telescopes with very short focal-length primary mirrors, aberrations being minimized by the use of Ritchey-Chretien optical systems. Although such optics are more difficult to figure, this disadvantage is more than made up by the advantages of a shorter, more rigid tube, smaller dome, and greater accessibility. Fused silica optics are used for greatest thermal stability, since they have about 1/5 the coefficient of thermal expansion of low coefficient glasses such as pyrex.

It is proposed that the 60-inch reflector have a fused silica primary mirror with a focal ratio of about $f/3$, with effective focal ratios of $f/8$ and $f/16$ at the Cassegrain focus and $f/42$ at the Coudé focus. Such a design will allow the use of either a single pier, asymmetric-type mount, or a fork-type mount. Figure 5 shows the new 48-inch reflector at the Dominion Astrophysical Observatory, an asymmetric-type mount; Fig. 6 is a schematic drawing of a 60-inch asymmetric telescope, kindly provided by Boller and Chivens (South Pasadena, Calif.), a firm of wide experience in the construction of such mounts. This mount has the advantages of access to the entire sky from the Coudé focus, with only four reflections, as opposed to five for the fork-type mount, and with much greater space for auxiliary equipment at the Cassegrain focus. It is also mechanically superior in some respects in that it easily avoids certain harmful flexures that occur at large hour angles in fork-type mounts. Figure 7 presents a schematic drawing of a fork-type mount designed by B. H. Rule, a leading authority in telescope design. This mount has the advantage of very small motion of the Cassegrain focus, thus facilitating observing, and of permitting use of the Coudé focus over a broad range of declinations, including the ecliptic, with the use of only three mirrors. Furthermore, the rebalancing of the telescope after equipment changes is somewhat simpler than with the asymmetric mount. A final choice between the two mount concepts will await detailed design and cost estimates. In either case, the short focal ratio will allow the use of a dome only 45 feet in diameter, a distinct cost advantage. The use of fused silica will allow both daytime and nighttime use of the telescope.

Much of the work with the 60-inch reflector will be at the Coudé focus, where it is possible to install large, massive, fixed auxiliary equipment. It is proposed to build

two separate horizontal Coudé rooms, light being fed to the appropriate room by an optical flat. This extra reflection allows the use of more than one Coudé room so as to provide greater flexibility in operation and the ability to accommodate several experiments concurrently. It also offers the safety, flexibility and economic advantages of horizontal rooms, while still requiring no more reflections (five) than the standard fork mount with inclined Coudé room, such as is employed with the 84-inch Kitt Peak reflector.

One Coudé room will contain a large fixed spectrograph of the most advanced possible design, optimized for use in red and near-infrared where many molecular rotation-vibration features lie. The beam diameter will be at least 8 inches, and provision will be made for the later

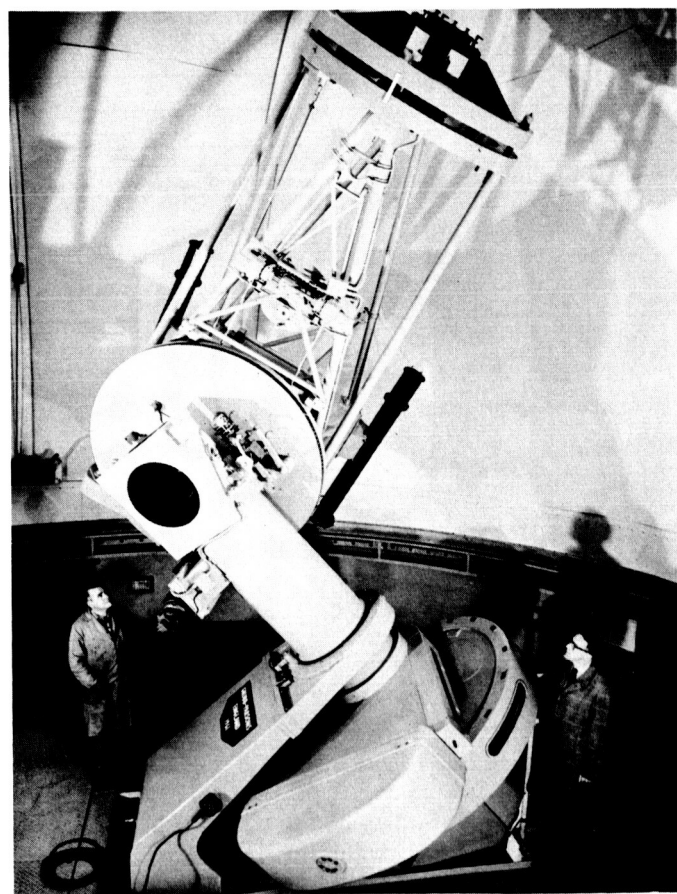


Fig. 5. Forty-eight-inch reflector, with asymmetric mount and Coudé focus, of the Dominion Astrophysical Laboratory, Victoria, B.C.

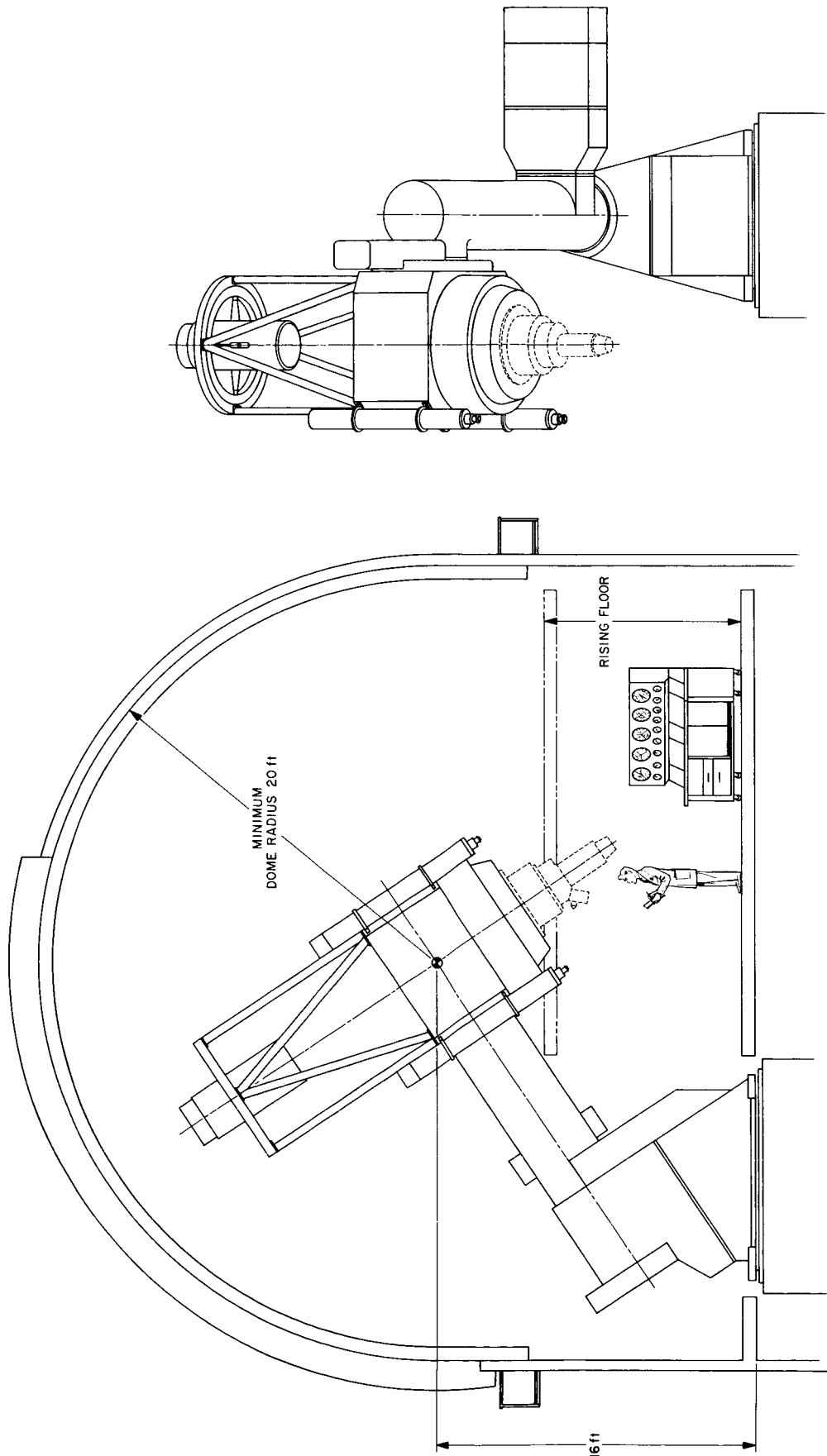


Fig. 6. Schematic drawing of a 60-inch telescope with asymmetric mount, based on designs by Boller and Chivens, South Pasadena, California

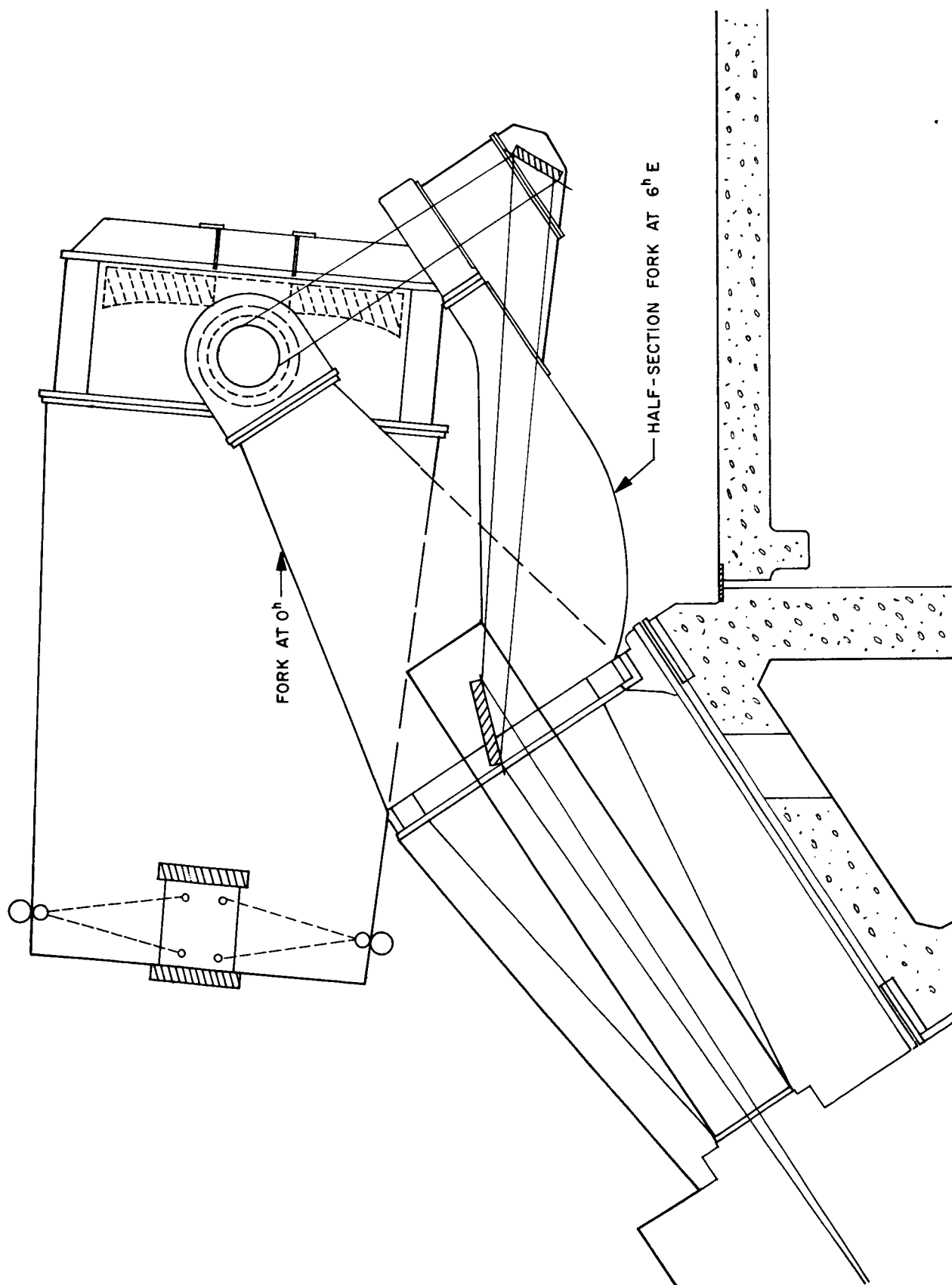


Fig. 7. Schematic drawing of a 60-inch telescope with fork mount, based on design by B. H. Rule

addition of a collimator of longer focal length, giving a larger beam diameter of about 12 inches, at such time as larger diffraction gratings become available. In planetary spectroscopy, high spectral resolution is presently most important. It is proposed that three to five cameras be constructed for the spectrograph, that of longest focal length to give a dispersion of 2 Å/mm in the red. Provision should be made for at least five separate gratings. The second Coudé room will be used for one or more spectrometers, visitor equipment, and for radiometric work.

Figures 8 and 9 present sketches of a representative layout for the observatory building. The dome is a classic 45-foot double shell, heavily insulated between the inner and outer surfaces, since, even with fused silica optics, it is desirable to maintain as much thermal stability as possible. It will have transverse shutters opening at least 5 feet beyond the zenith, with windscreens coming from above and below. A heavy-duty crane will be permanently mounted in the top of the dome for construction and maintenance of the telescope. If funds permit, the floor may be designed to elevate 5 to 10 feet for easy

access to the telescope. The usual darkroom, ammoniating room, and lounge-office are included.

The Coudé rooms will utilize the thermal inertia of massive concrete walls and ceilings for thermal stability. Temperature in these rooms should vary a maximum of $\pm 1^\circ\text{C}$ in 8 hours. The roofs over the spectrograph rooms, and other rooms as well, will be designed to introduce the minimum possible microthermals and other seeing effects into the optical path of the telescope.

The darkroom will require air-conditioning and heating equipment to maintain a temperature very near 68°F. Provision is made for a separate ammoniating room in which to hypersensitize infrared photographic plates. This room will require a large flow of filtered (dust- and particle-free) air at a reasonable working temperature. The library-lounge-workroom will require heating. Other rooms will not be heated or cooled in any way.

Details may be expected to change as actual design progresses, but it is not anticipated that there will be significant departures from the present proposal.

NOTES:

1. THE MAIN PIER AND ALL INSTRUMENT PIERS MUST BE VIBRATION-INSULATED FROM THE REMAINDER OF THE BUILDING. EXACT LOCATION OF PIERS AND SLITS CANNOT BE DETERMINED UNTIL THE OPTICAL DESIGN IS COMPLETED
2. WALLS OF SPECTROGRAPH AND SPECTROMETER ROOMS SHOULD BE SOLID CONCRETE AT LEAST 12 in. THICK

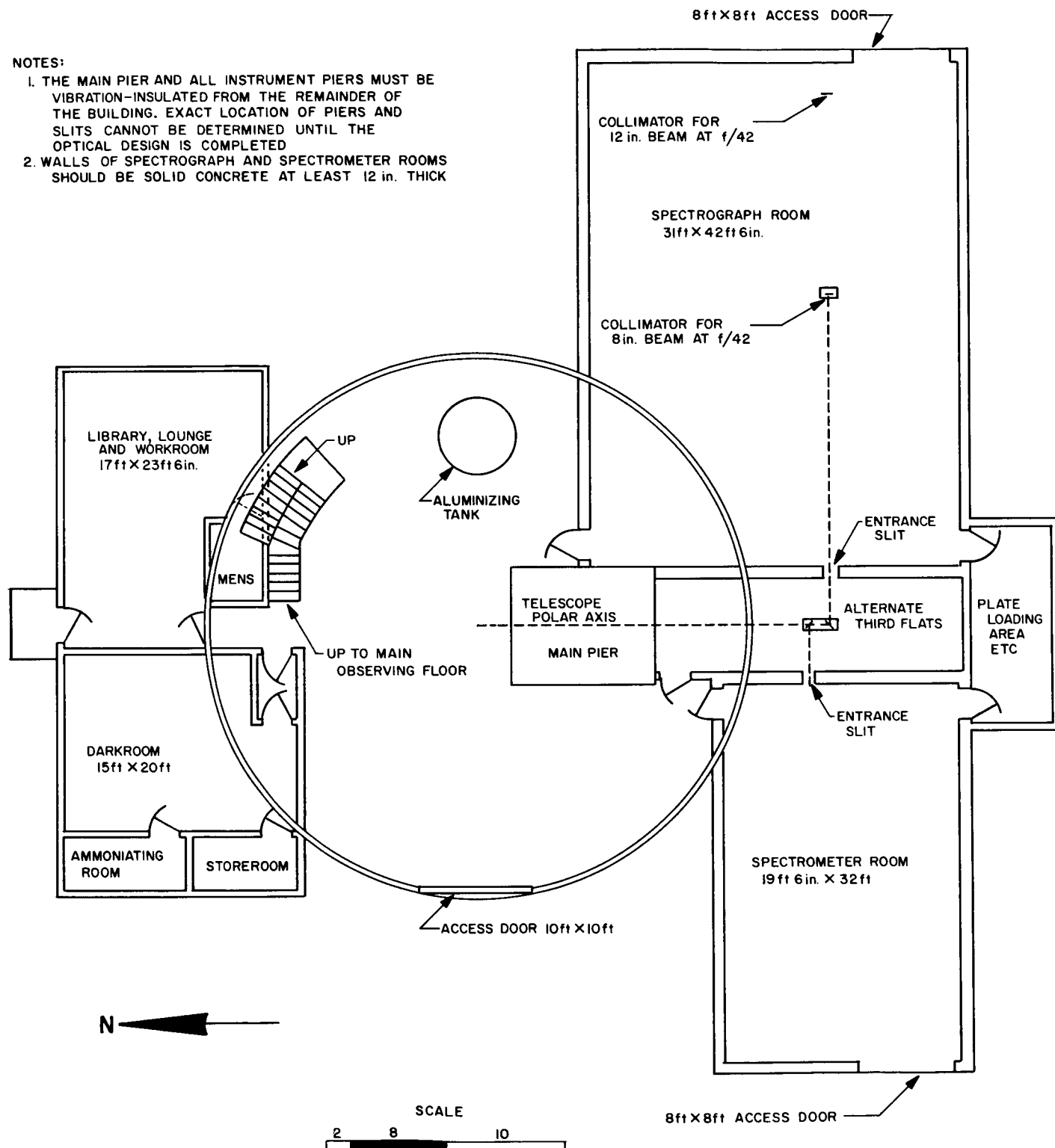


Fig. 8. Schematic drawing of telescope dome and associated Coudé rooms, etc., plan view

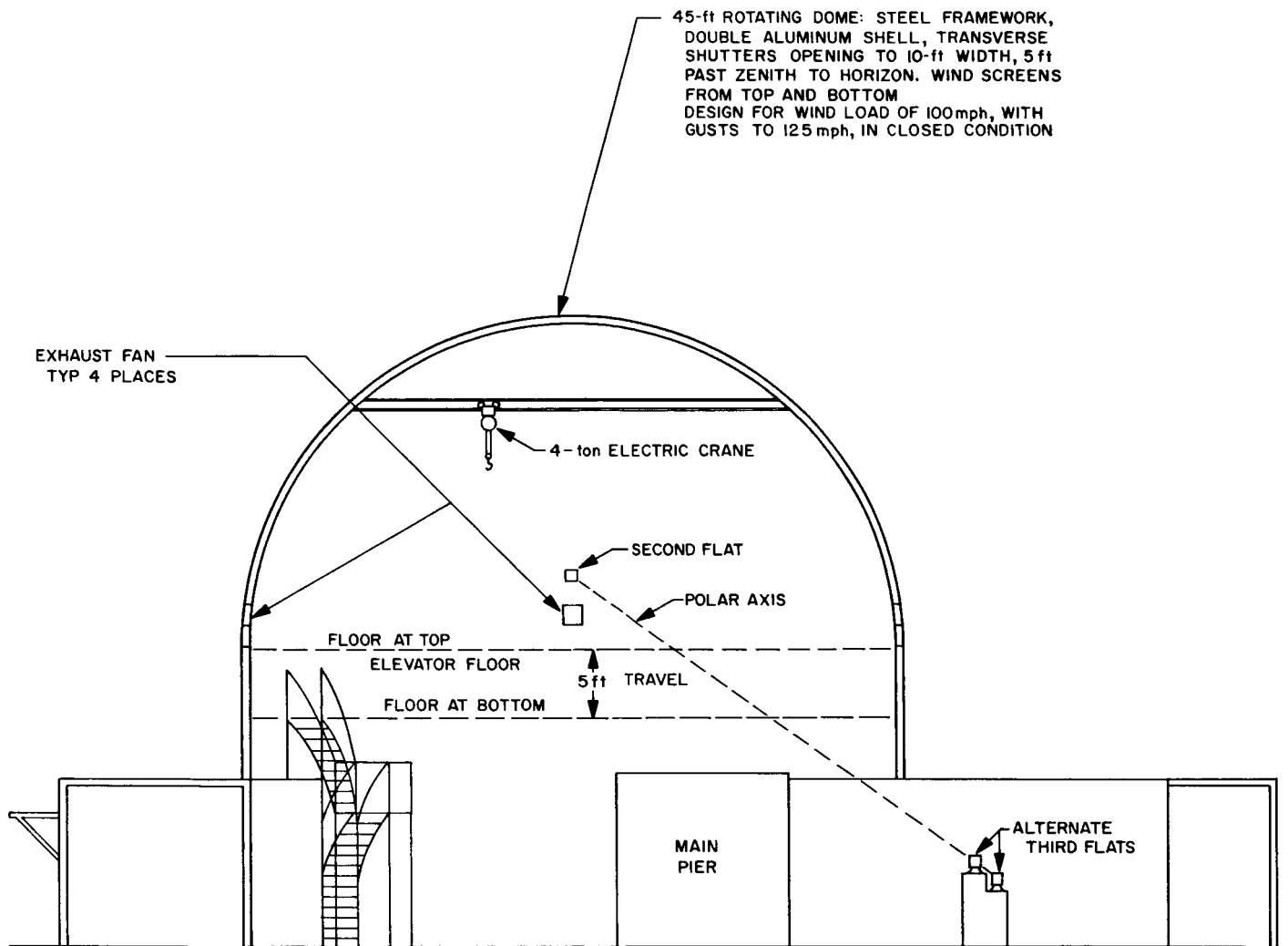


Fig. 9. Schematic drawing of telescope dome and associated Coudé rooms, etc., sectional view

IV. THE PROGRAM

With a 60-inch telescope devoted to solar system research, it will be possible to attack a broad range of outstanding problems. First, it will be possible to investigate several important lunar problems. These include the possibility of making physical measurements on active, possibly outgassing or erupting, small regions on the Moon. Is the escaping matter a cool gas, a hot gas with strong molecular and atomic emission lines, or merely dust? Spectroscopic observations of activity such as the recent red spots near Aristarchus can differentiate between these possible origins. Another potentially very enlightening study is the study of lunar luminescence. Is it really strong enough to fill in the profiles of Fraunhofer lines, and what is the spectral range? Does it depend upon solar activity and location on the Moon, or is the effect satellite-wide? What does it say of lunar mineralogy? Observations of lunar luminescence are well within the capabilities of this instrument.

All the planets with atmospheres present interesting, and somewhat individual, problems. One goal of the program is to establish the molecular compositions of planetary atmospheres; even now the compositions of stellar atmospheres are better determined than those of planetary atmospheres. Part of the problem is that the abundant homopolar gases H_2 and N_2 do not *ordinarily* produce planetary spectral lines in regions accessible to Earthbound observers. However, the pressure-induced dipole bands of N_2 and H_2 and the sharp quadrupole lines of H_2 lend promise for quantitative analysis of even these molecules if they are present in large amounts (Refs. 3 and 4).

The near-infrared Venus CO_2 bands may be used for abundance, temperature, and pressure measurements (Ref. 5) and even for isotopic abundance ratios (Ref. 6). The phase-dependence of these parameters is now under study, but large numbers of high-dispersion spectra are needed to convert the observational quantities into model atmospheres of some use in entry capsule design, for example. The simple question of the O_2 abundance on Venus has not yet been settled; all that is required are new spectra at the appropriate phase angles.

Recent ground-based results indicate an H_2O abundance of some 14μ over the Martian south pole. Is this value typical for the planet as a whole over long periods of time? We have determined an approximate spectroscopic surface pressure of 25 mb for Mars and a large

CO_2 abundance. These important values are subject to improvement by spectroscopic observations well within the capabilities of the 60-inch reflector proposed here.

The outer planets also present a large number of interesting problems. What are the abundances of the light gases, hydrogen and helium, in the major planets? Preliminary work here indicates that the absolute H_2 abundance above the planetary clouds increases outward from the Sun, but the H/C ratio may decrease to a value far below the corresponding cosmic ratio (derived from hot stars and the Sun). It may also be possible to establish the D/H isotope ratio in the outer planets from the HD dipole lines in the near infrared. The C^{12}/C^{13} ratio may be found from a detailed study of the methane spectrum. It is planned to study these important problems, and, undoubtedly, many new problems, such as the variable NH_3 "wind" of Jupiter.

The power of radiometry in the 10μ atmospheric window has been demonstrated recently. The telescope will be very useful for such observations, and will capitalize on the high altitude and dry climate at Table Mountain.

Planetary photometry, and particularly polarimetry, have demonstrated that these techniques may contribute decisively to the elucidation of surface structure and perhaps problems of exobiology. Observations at the Cassegrain focus will permit the exploitation of these possibilities.

The expected optical performance of the telescope and the good seeing conditions at Table Mountain will permit a program of superb planetary photography. Using the high-speed emulsions now available and the technique of composite photography, improvements over existing resolution should be obtained. The availability of the telescope should insure that lengthy synoptic photographic programs with a powerful instrument may be supported.

These are examples of problems in lunar and planetary astrophysics which should be investigated from terrestrial observatories and which will be within the capabilities of this instrument. Table 1 presents a schedule of the special opportunities for planetary observations that will occur during the next 8 years. It is obvious that a large portion of the available observing time can be utilized profitably in solar system research.

Table 1. Table of best opportunities for planetary observations

	1964		1965		1966		1967		1968		1969		1970		1971	
	1-1	7-1	1-1	7-1	1-1	7-1	1-1	7-1	1-1	7-1	1-1	7-1	1-1	7-1	1-1	7-1
VENUS INFERIOR CONJUNCTION	X				X		X				X		X			
MAXIMUM RELATIVE RADIAL VELOCITY	X				X		X				X		X			
SUPERIOR CONJUNCTION									X						X	
MARS OPPOSITION																
MAXIMUM RELATIVE RADIAL VELOCITY																
JUPITER OPPOSITION																
SATURN OPPOSITION																
ENCKE'S COMET PERIHELION																
TOTAL NUMBER OF ABOVE OPPORTUNITIES PER SIX-MONTH INTERVAL	3	4	3	3	2	2	4	5	1	2	1	6	1	3	4	3

- Lunar observations (w/flight data)*
1. Simultaneous observations during encounter
 2. Two - 3 facilities req'd. - weather & type of work
 3. Spectrographic capability on demand
 4. Other plots

V. OPERATION OF THE TELESCOPE

It is proposed that the 60-inch telescope be used almost solely for solar system research. The programs outlined above are already more than sufficient to occupy fully the time of such an instrument. Telescope time will be assigned to other programs only when they are of wide interest and can make great progress through use of the almost unique abilities of the proposed instrument.

The telescope observing program will be determined by the observatory director, who will be guided by an advisory committee composed of experienced personnel from JPL, the California Institute of Technology, and the Mt. Wilson and Palomar Observatories, and will in-

clude representation from NASA if it is felt desirable. This committee will meet as frequently as required, perhaps quarterly, to provide timely recommendations to the observatory director.

JPL will manage the instrument as a national facility. Following the guidelines generally used at existing national observatories, a large fraction of the telescope time will be reserved for JPL staff, with the remainder of the time to be available to qualified visitors. It is expected that these will include scientists from NASA centers. Proposals for research by graduate students will be particularly encouraged.

VI. THE TABLE MOUNTAIN SITE

This proposal is based on the premise that the telescope will be erected at the existing Table Mountain site, which has proved to be a superb location. A year of operation at Table Mountain has confirmed the conclusions of observers who have used the site over its 40-year history as an astronomical observatory. During the first year of operation, records indicate that seeing was better than 0.8 more than 30% of the total observing time, and about 7% of the time better than the 0.3 diffraction limit of the 16-inch reflector. This is better than has been found in any other published seeing survey.

The Table Mountain site is high (7500 feet) and dry, being basically a semi-arid region. Three nights during the winter of 1962-3 found the relative humidity less than 10% when the temperature was below zero Fahrenheit. Relative humidity less than 10% is quite common, although temperatures below zero are not. The site is sufficiently dry to greatly expedite most programs of infrared spectroscopy. It is unlikely that a drier site could be found without going far afield to much higher sites which would probably suffer from high winds and,

therefore, poor seeing. Table Mountain has an average of 5½ feet of snowfall annually. By comparison, White Mountain, often mentioned as a possible high and dry observatory site, has a mean annual snowfall in excess of 13½ feet.

The fact that the Table Mountain site is already physically developed with power, water, telephones, and a paved road is a great financial advantage. The site is far enough from Los Angeles to escape smog and lights, yet close enough to JPL and Pasadena so that it may be reached in two hours even during the winter when the shortest Angeles Crest Highway route is closed.

A peculiar problem of the Table Mountain site is its proximity to the San Andreas Fault, the boundary of which passes only a few hundred yards to the south. A detailed report by T. M. Leps, registered professional engineer and specialist in construction in earthquake-prone areas, has furnished three economical schemes for foundation construction which "if carried out to prudent extent, would furnish an adequate, aseismic foundation for the

proposed telescope and structures." He and other competent engineers consider the proximity of the fault to be of little consequence for structures of the size contemplated. Aseismic structural design will increase costs negligibly. It may be noted that this region of the San Andreas fault has not produced a major earthquake in over 100 years, and there is no evidence of catastrophic earthquakes over recent geological history.

Looking to the future, as soon as funds and personnel permit, JPL intends to conduct seeing and water vapor studies at several other sites in the Southwest. The goal will be to find sites that are markedly superior to the Table Mountain site for planetary observing. Any site so found may be used for future larger instruments, or, if found in time, could be the site for the instrument proposed here.

VII. COST ESTIMATE

The cost estimates which follow are based upon conversations with such firms as Boller and Chivens, Corning Glass, Davidson Optonics, and Fecker, as well as the JPL plant planning staff. It should be noted that each component of the telescope is closely similar to something already produced commercially. Thus no development work is required, and the figures given below are based on more than one past actual procurement of the same item or service.

Fused silica mirror blanks (1:6 thickness ratio)	\$ 100,000
Small mirrors	15,000
Figuring	100,000
Mounting	350,000
Mount engineering	35,000
Building (45-ft dome)	325,000
Darkroom equipment, furnishings, etc.	25,000
Coudé spectrograph	250,000
Total	\$ 1,200,000

Contracts for these items should be let during the initial year of the project.

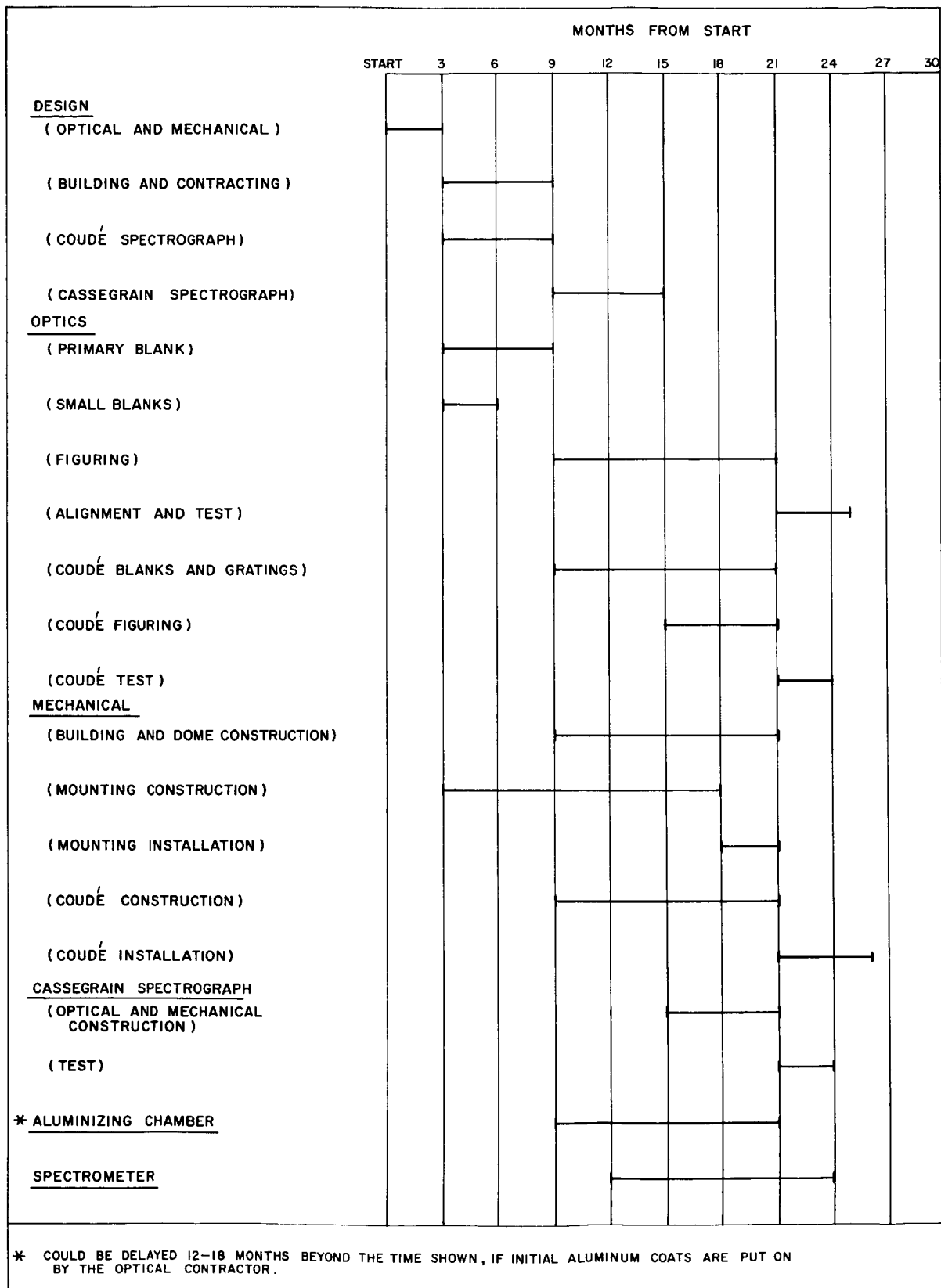
The following additional equipment should be furnished during the first year of telescope operation.

Cassegrain spectrograph	\$ 60,000
Spectrometer	120,000
Aluminizing tank	80,000
Total	<u>\$ 260,000</u>

These items will complete the basic facility. The cost of maintaining and supporting the observatory with the latest equipment, exclusive of salaries, would be from \$100,000 to \$200,000 per year over the foreseeable future.

Table 2 presents a tentative time schedule for construction of the telescope. Based on conversations with commercial telescope builders, this is a reasonable schedule. It might be shortened four months if an extraordinary effort were made.

Table 2. Schedule of telescope construction



VIII. SCIENTIFIC STAFF

The members of the JPL staff who would be directly associated with the telescope are given below, along with their personal résumés. Although the laboratory has a considerable staff of professionals experienced in mechanical and optical design, it is recognized that most of this experience was gained from non-astronomical activities. It is expected, however, that such experience will be helpful in undertaking the direction and control of suitable contractors selected to carry out the actual telescope work. In addition, we will utilize the services of Dr. Ira Bowen, Director of Mt. Wilson and Palomar Observatories, and Mr. Bruce Rule, in charge of the Central Engineering Department at the California Institute of Technology, who have agreed to aid in the evaluation of optical and mechanical design. Also, it should be noted that private firms which construct telescopes have now developed their facilities to such an extent that all components of a telescope of the proposed type and size are readily available commercially. In fact, a 60-inch telescope of superb quality is now easily obtained as an "off-the-shelf" item.

With the staff given below, it is felt that efficient operation of the telescope would require additionally only the acquisition of two observing assistants.

Roland L. Carpenter

Mr. Carpenter has been with JPL since 1959. He was involved in the tracking and orbit determination problems of the *Echo* communications satellite experiment, especially as it related to the effects of solar light pressure on the orbit. He was associated with JPL's 1961 Venus radar program and the study of the radar spectra of the planet. He was an experimenter on the 1962 Venus and Mars radar programs.

He received his M.A. from the University of California at Los Angeles in astronomy (1963) and is continuing his studies there toward his Ph.D. degree in astrophysics.

Frank D. Drake

Dr. Drake received his B. Eng. Physics from Cornell U., in 1952, and his M.A. and Ph.D. in Astronomy from Harvard University, in 1956 and 1958, respectively. He served as an electronics officer in the U.S. Navy. Later he was a member of the Harvard University Radio Astronomy Project and Director of the Astronomical Research Group of the Ewen Knight Corporation. He

joined the staff of the National Radio Astronomy Observatory in 1958 in the early stages of the development of that institution. There he participated in the development of major radio telescopes and in galactic and planetary radio astronomy research. He became Head of the Telescope Operations and Scientific Services Divisions of the Observatory and was Director of Project Ozma, the first organized high-sensitivity search for extraterrestrial intelligent radio signals.

He assumed his present position as Chief of the Lunar and Planetary Sciences Section in the fall of 1963.

Warren A. Hovis, Jr.

Dr. Hovis has been at JPL since May, 1962. He is presently engaged in the design and construction of two large absorption tubes for studies of gases prominent in planetary atmospheres. He is also engaged in the development of spectroscopy instrumentation for astronomical telescopes and infrared spectrometers for space probes. Dr. Hovis was previously at General Electric, Missile and Space Vehicle Department, where he did time-resolved spectroscopy of highly ionized plasmas. He received his A.B. (1953) and Ph.D. (1961) in physics from Johns Hopkins University.

At Johns Hopkins, Dr. Hovis studied time-resolved spectra of highly ionized rare earth ions and for two years was instructor in experimental spectroscopy.

Douglas Jones

Mr. Jones has been at JPL since 1960. He received his B.S. (1957) and M.S. (1959) in physics at Brigham Young University. His work there included the lithium 7 magnetic moment in Bohr magnetons at K band. He was an experimenter on the Venus mission—*Mariner R* (1962). He is presently working toward a Ph.D. in physics at Brigham Young University.

Lewis D. Kaplan

Dr. Kaplan received his Ph.D. in meteorology from the University of Chicago (1951), where he started work in the field of atmospheric heat transfer. He has had a major role in the modern development of this field and, in the past year or two, its application to the atmospheres of planets, particularly Venus. He has been a member of the Institute for Advanced Study as well as the staff of

Imperial College, London, and Massachusetts Institute of Technology. He is part-time Professor of Atmospheric Physics at the University of Nevada. He joined JPL in 1961, where he is Staff Scientist to the Space Sciences Division Office, working on interpretation of data on planetary atmospheres.

He has been selected as experimenter for the various infrared experiments on Venus and Mars spacecraft.

He is Chairman of the A.G.U. committee on Atmospheric Radiation and Optics and a member of the NASA Planetary Atmospheres Subcommittee and the Committee on Radiation Energy of the American Meteorological Society.

Robert V. Meghreblan

Dr. Meghreblan has been Chief of the Space Sciences Division since 1962 and in that capacity is responsible for organizing and directing the major portion of the basic scientific research at the Laboratory and the conception, design, and development of spacecraft scientific instrumentation.

He held the appointment of Associate Professor in Applied Mechanics at the California Institute of Technology during the academic year 1960-1961. He joined the Laboratory in 1958 as Chief of the Physics Section, and was appointed Head of the Physical Sciences Division in 1960.

Formerly he was with the Oak Ridge National Laboratory (1952-1958), where his positions included Associate Director, Gas Cooled Reactor Project; Head of Applied Mechanics Group, ANP Program; Reactor Physicist on the ORNL Research Reactor and Army Package Power Reactor; and Lecturer in Reactor Analysis at ORSORT.

Dr. Meghreblan completed his undergraduate study at Rensselaer Polytechnic Institute in 1943. His graduate work was carried out under a Guggenheim Fellowship at the California Institute of Technology; he received his Ph.D. in aeronautics and mathematics in 1953.

Dr. Meghreblan is co-author of the text *Reactor Analysis* published in 1960 by McGraw-Hill Book Company.

Billy L. Meredith

Mr. Meredith began work at the National Radio Astronomy Observatory in the fall of 1958. He received his B.S. (1959) in physics and math from West Virginia State

College. Work at NRAO consisted of operating radio telescopes, operating and maintaining radiometers and associated electronic equipment, and reducing and analyzing data. He joined JPL in the fall of 1963.

Ray L. Newburn

Mr. Newburn received his B.S. (1954) and M.S. (1955) in astronomy from the California Institute of Technology. Since then he has obtained a number of additional C.I.T. graduate credits. His work there was in the field of observational astrophysics.

He joined JPL in 1956 and has worked in the fields of meteorology, aeronomy, ionospheric physics, and astrophysics of the planets. He is the present supervisor of the Table Mountain Observatory, and has been concerned with the operation of the television system for the 1964 Mars *Mariner* probe, and lunar synoptic observations.

He is a former member of the NASA Astronomy Subcommittee.

Justin J. Rennilson

Mr. Rennilson has been employed at JPL since March, 1961, as a Senior Scientist in the Photoscience Group of the Applied Sciences Section of the Space Sciences Division. He is mainly concerned with problems of lunar photometry and spectroscopy and *Surveyor* Project photography.

Mr. Rennilson received an A.B. degree in astronomy from the University of California, Berkeley and Los Angeles in 1950. During 1953-55 he took two years of graduate work toward a doctorate in the fields of optics, photometry, and colorimetry at the Optical Institute, Technical University of Berlin, Germany. From 1955 to 1961 he was employed by the Visibility Laboratory of the Scripps Institute of Oceanography, University of California at San Diego, as Associate Engineer in the fields of hydrological and meteorological optics instrumentation. He was a member of the part-time faculty of the Astronomy Department, San Diego State College, 1956-1961, and an observer in the IGY Program at San Diego State College, 1957-1959. Mr. Rennilson was consultant to General Dynamics Corporation, Stromberg-Carlson Division, San Diego, 1956-1960.

Takeshi Sato

Dr. Sato received his B.S. (1954) and M.S. (1955) in electrical engineering from the California Institute of

Technology. He received a Ph.D. (1960) in electrical engineering from Stanford University, specializing in microwave electronics.

Dr. Sato has been employed at JPL since 1960 as a Senior Research Engineer in the Telecommunications Division, transferring to the Space Sciences Division in 1962.

In the Telecommunications Division, Dr. Sato was responsible for the design, development, and operation of reliable maser systems for deep-space tracking. His work in the Space Sciences Division is with millimeter-wavelength radiometer systems for Mars and planetary investigations.

Ronald Schorn

Dr. Schorn joined the Laboratory in 1962 and is working on planetary radar studies and planetary surface photometry. Dr. Schorn is a graduate of Loyola University of Chicago (1956) and received his M.S. in physics (1958) and Ph.D. in astronomy (1962) from the University of Illinois. While at Illinois he received intensive training in observational astronomy at the Yerkes Observatory of the University of Chicago. Also at Illinois he undertook investigations in radio and radar astronomy and the structure and time variations of the Earth's ionosphere and upper atmosphere.

Hyron Spinrad

Dr. Spinrad joined JPL in 1961. He now specializes in high-resolution spectroscopy of the planets and analysis of the compositions and thermal properties of planetary

atmospheres. He obtained his Ph.D. at the University of California, Berkeley, in 1961, where he was concerned with photoelectric photometry of variable stars and the stellar content of galaxies. Dr. Spinrad held a Lick Observatory Fellowship from 1958 to 1961 and was Dorothea Klumpke Roberts prize winner in 1959. He is a member of the Astronomy Subcommittee.

Robert Younkin

Mr. Younkin has been with JPL since August, 1961. During this period he has been primarily engaged in determining the spectral energy distributions and monochromatic reflectivities of the planets with a scanning monochromator at the Mt. Wilson 60-in. telescope. He has also recently carried out photography of Venus at inferior conjunction.

Prior to coming to JPL he was a member of the technical staff at Space Technology Laboratories (1955-1961). Among the problems he worked on at STL were radiative transfer in planetary atmospheres, determination of reflectivity of local areas of the Moon as a function of phase angle and angles of incidence and reflection, and the effect of the Earth's atmosphere on long-range photography. In addition he has done research on density transients in superheated liquids at the UCLA Engineering Research Laboratory (1952-1953), and in nuclear physics at the University of California Radiation Laboratory (1948-1951).

He holds a B.A. (1947) and M.A. (1951) in physics from the University of California at Berkeley and is doing his Ph.D. Thesis at UCLA.

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